Flowers, Bees, Butterflies and Biodiversity

Measuring the effectiveness of management strategies on biodiversity along the flood defences of the River Lek.

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Introduction

Climate change has negative effects on the growth and survival of plants, the existence of animals and water levels (Thomas et al., 2004). In the Netherlands, two sustainability issues caused by climate change are abundantly present: the loss of biodiversity (Rijksoverheid, 2013) and rising water levels (KNMI, n.d.). The Netherlands is vulnerable regarding sea level rising; 26% of the land lies beneath the sea level and 59% of the land is susceptible to flooding. Consequently, 55% of the land is protected by dikes or dunes (Planbureau voor de Leefomgeving, n.d.). Second, the country's biodiversity is exceptionally low compared to other countries. While climate change is one reason for this, the main cause is land use change. This consists of intensification of agriculture, which resulted in loss of biodiversity (Haveman, 2006). The Mean Species Abundance in the Netherlands is only 15%, meaning that compared to natural settings only 15% of the population is present. The average MSA in Europe is about 40%, indicating that the biodiversity is below average in the Netherlands (Rijksoverheid, 2013). Therefore, increasing biodiversity in the Netherlands through improved management of both natural areas and urban areas is vital.

Because of this vulnerability, it is of great importance that the dikes are improved regularly. Apart from having dikes to prevent flooding, it is also important to give the river enough space before reaching the dike: this is called floodplains. Another important aspect that improves the quality of the dikes is a high level of biodiversity, since the roots of plants make the dikes less vulnerable to erosion (Berendse et al., 2015; HDSR, 2018; Liebrand, 1999; Van Loon-Steensma, 2017). This is where the two sustainability issues are connected.

Multiple projects have been launched to increase the biodiversity along dikes. In this paper, the focus will be on the Lekdijk, which protects a large part of the Randstad, and is 55 km long (HDSR, n.d.). The regional water board Hoogheemraadschap de Stichtse Rijnlanden (HDSR) is responsible for its management. HDSR is a governmental body concerned with local and regional water management (HDSR, n.d.) in this specific area. HDSR has started a project to manage biodiversity along the Lekdijk. However, it is not clear whether the change in management makes a significant difference in biodiversity. In response to this project, this research is set up to investigate and map the biodiversity along the Lekdijk. The biodiversity change will be measured using multiple biodiversity indices further explained in the method section of this paper.

This leads to our research question: **How does the management of plant species affect biodiversity along the Lekdijk?**

To complement our research questions, sub-questions have been defined:

- How does plant species richness, evenness, abundance of individuals, and the Shannon Index differ between managed and unmanaged sites?
- How do butterflies and bees differ in the populations and abundance between sites?

A hypothesis has been formulated on which the research and discussion will be focused: The management of flowers along the Lekdijk will increase the biodiversity of plant and pollinator species.

Literature review

Climate change, *inter alia*, has been linked to changes in spatial and temporal patterns of biodiversity, and rising sea levels. The subject of climate change and biodiversity is already a well-established research area; the Intergovernmental Panel on Climate Change (2002) has done extensive amounts of research on this issue and has concluded that climate change is negatively affecting biodiversity around the world and increasing the global sea level. This is further supported by Van Koningsveld et al. (2008) who looks at the impacts of rising sea levels caused by climate change in the Netherlands. Van Koningsveld et al. (2008) states that due to the geological characteristics of the Netherlands being below sea level, the Netherlands will be vulnerable to increasing water levels and other “extreme climatic events” associated with climate change. While both papers acknowledge the dangers of rising sea level and advocate towards strengthening water defense systems such as dikes in low-lying countries, neither consider incorporating biodiversity as an attempt to mitigate this issue.

Multiple other papers (e.g. Berendse, 2015; Liebrand, 1999; Van Loon-Steensma, 2017), on the other hand, have discussed the importance of biodiversity in the conservation of nature and fortification of river dikes. All three papers uniformly iterate that with the inclusion of flora species and other diverse plant communities, river dikes are less likely to experience soil erosion due to the extensive root systems holding the soil together. When comparing the literature, it had become apparent that only Berendse (2015) does not include or refer to forms of management in its report, as the paper was only looking analytically at the relationship between biodiversity and soil erosion without giving any solution oriented perspective on its research. Moreover, the more obscure and broader benefits of biodiversity richness seem to be missed by all three of the papers due to their focus on the benefits only towards dikes. They do not include the surrounding environment and its potentially positive effect on fauna populations.

This leads to the following research done on insect decline (especially pollinators) as a result of biodiversity recession. Hoffman’s article (2008) correlates the decline in plant and insect species with the decrease in pollination and thus the reproduction and maintenance of plant communities. Biesmeijer (2006) contradicts this by stating that there is no clear distinction whether the reduction in pollinator species precedes the reduction in plants or vice versa, or that both factors are reacting to some other external factor. It is not clear which conclusion should be considered over the other, however, both papers and countless more (e.g. Westphal et al, 2008; Blüthgen, 2011; Elle, 2012; and Rathcke, 1993) do establish the point of a mutualistic relation between plant and pollinator species and their crucial codependence on each other, which has prompted a developing interest to look further into this correlation within this report.

Moreover, two other papers suggest a positive correlation between increase in ambient temperature and thermophilic species growth (Feest, 2014; Tamis, 2005). Feest (2014) relates this correlation to its effects on local pollinator species in the Netherlands, specifically butterflies. This causal response from climate change is due to "many temperate region populations [...] extend[ing] their geographic range as temperatures increase" (Feest, 2014). Tamis (2005), on the other hand, fixates its paper on the observation of changes in vascular plant biodiversity with no mention of the corresponding effects on dependent fauna species giving a more limited view on the issue.

In line with this, proper management strategies of retaining high plant biodiversity is a crucial determining factor for the success of pollinator species. In a significant number of texts, management of biodiversity has been a great focus of interest (Berendse, 2015; Van Loon-Steensma, 2017; Liebrand, 1999; Humbert 2012; Cizek, 2011; Smith, 2018; HDSR, 2016). The mowing of river dikes, among other things, is a commonly practiced method within the Netherlands to help promote biodiversity and prevent erosion. By means of mowing, flora species are encouraged to grow, promoting denser root systems. Mowing also reduces competition and maintains semi-natural grasslands (Humbert 2012). Lastly, HDSR's (2016) method of mowing within the first two weeks of June supports Humbert's (2012) recommendation of delaying the date of first "mowing from spring to summer [which] had a positive effect" on plant species richness. Clearly, there is an abundant amount of inter-academic support on the management strategies for maximum performance efficiency.

Nonetheless, while the success of mowing to increase biodiversity as a strategic management approach for river dikes has been proven many times over (Van Loon-Steensma; 2017; Humbert, 2012; HDSR, 2016), few studies have investigated the combined effect of management strategies on plant *and* insect biodiversity and their interrelated connection with each other. The studies already conducted almost always focused on either plant biodiversity or insect (pollinator) biodiversity.

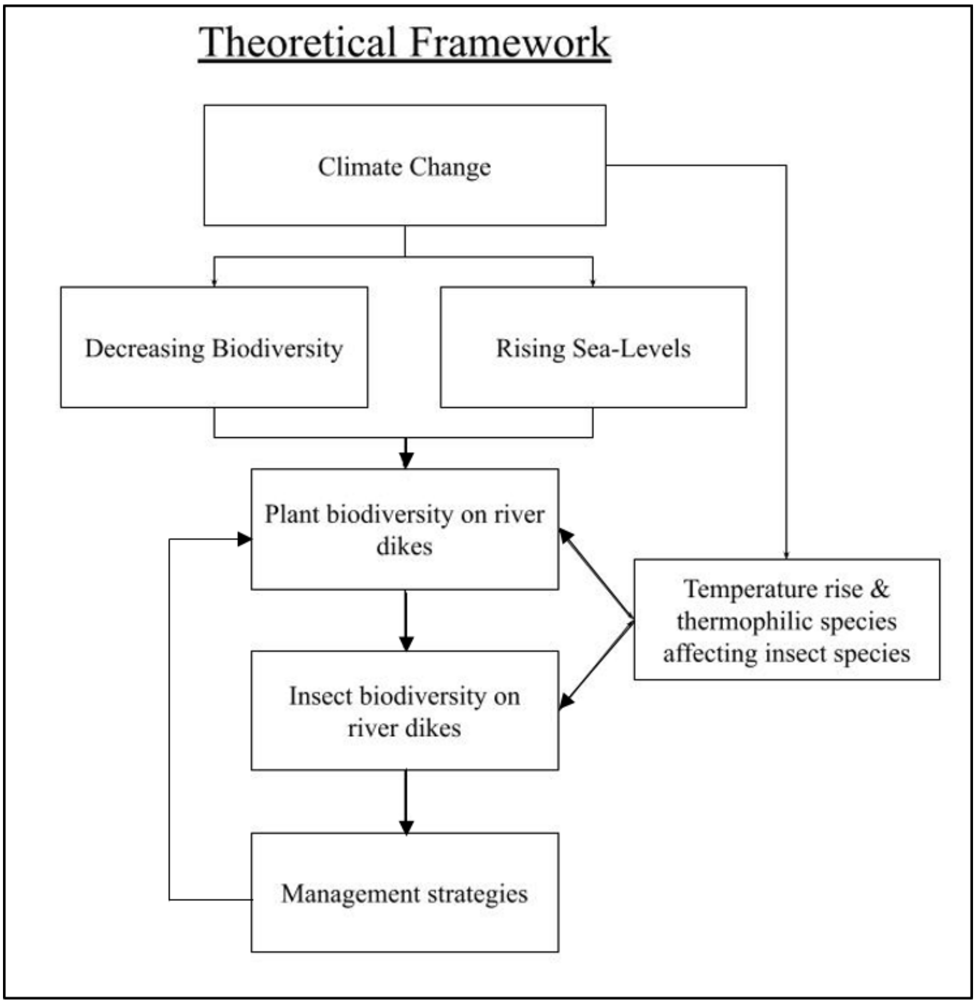


Figure 1: Theoretical framework showing the different aspects of this research and showing the connections between them.

Method

Preliminary Study

To begin, HDSR was contacted asking if they could provide the exact GPS locations of the managed zones along the Lekdijk, as the map that was provided in a PowerPoint presentation by HDSR (**Figure 2 & 3**) didn't specify the locations. Then, using QGIS, the GPS locations were inserted and, at random, the locations that would be researched were chosen (**Figure 4**).

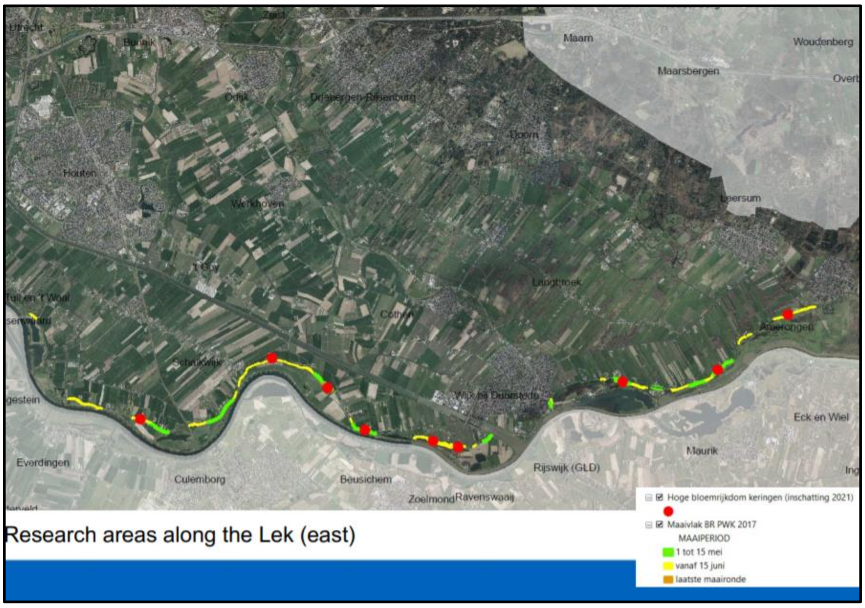


Figure 2: Map 1 used in the PowerPoint presentation by HDSR indicating the research areas along the Lek in the East.

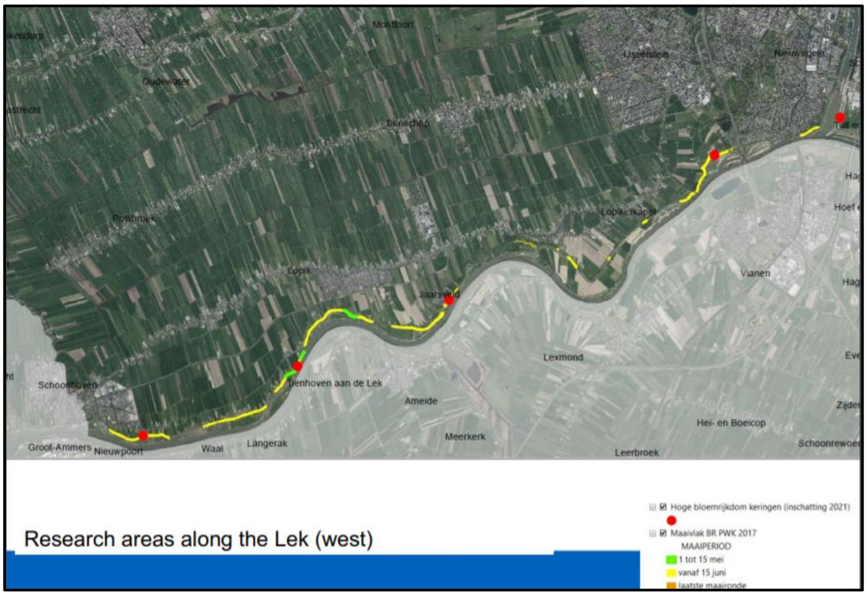


Figure 3: Map 2 used in the PowerPoint presentation by HDSR indicating the research areas along the Lek in the West.

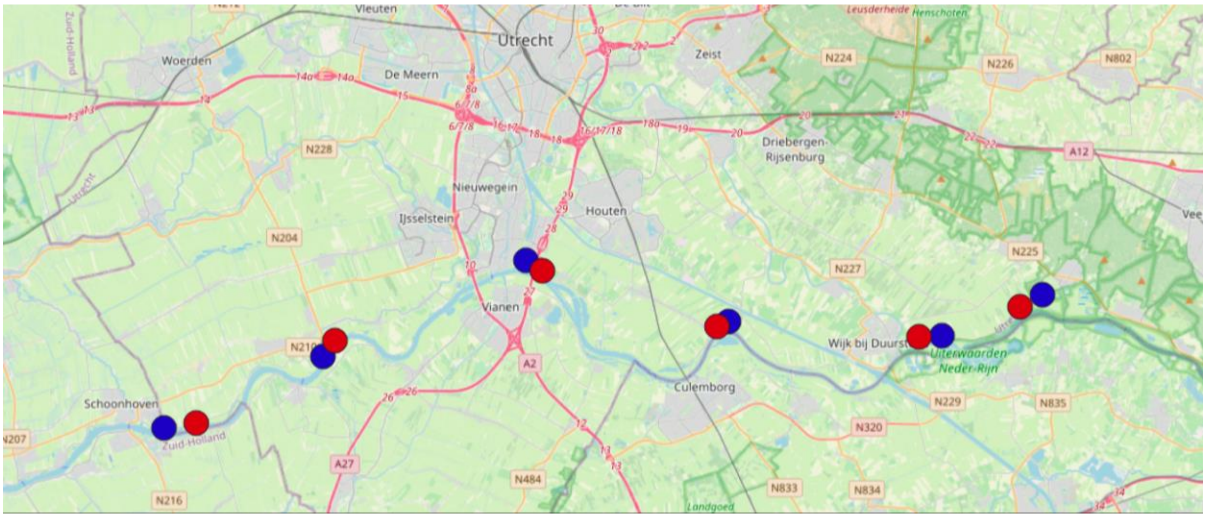


Figure 4: Map showing the locations where the research has been conducted and the locations that will be compared, the blue dots indicate managed sites, while the red dots represent the unmanaged sites.

Data Collection

To answer one of the sub-questions, it was required to identify butterfly species. The 'Floron's Zoekkaart Nectarplanten' was used (*Mijn berm bloeit!*, 2021) (**Figure 5 & 6**), which was printed and given to the researchers.

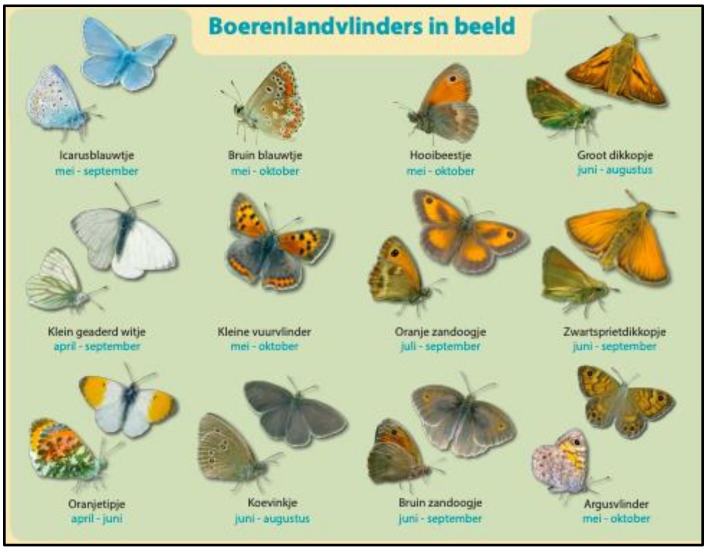


Figure 5: Species Index for butterflies, portraying the butterflies that can potentially be found at the site.

Figure 6: Species Index for plants, portraying the plant species that can potentially be found at the site.

The fieldwork was done in pairs; each pair received a managed and unmanaged location to visit. In total, data was collected from 12 different locations. In each of these locations a method for assessing biodiversity, a type of ecological census L. L. Eberhardt described in the 1978's article *Transect Methods for Population Studies*, was applied. In this article multiple transect methods are discussed, such as the Strip Transect which we focused on specifically, as well as the Sampling Design which works with systematically chosen individual sections within the transect area which is referred as "subareas", i.e. quadrants.

Floron's campaign, an organization that researches and protects the Dutch wild flora (*Mijn berm bloeit!*, 2021), also employed the Strip Transect method with a sampling design. The specific measurements of their campaign involved tracing a 100m verge that was divided up every 10m at which we would set up a quadrant of 1m x 1m square. It is important to add that in our experiment the flowers were counted from the stem instead of counting each individual flower 'head'. This was done a total of 11 times for each transect (instead of 10 times as we also made a quadrant at 0 meters). The results were then compiled in a spreadsheet as shown in **Figure 8**.

It was noted that butterfly and bee subjects are not static which would make it more challenging to measure. To decide on the method to use for counting bees and butterflies, studies such as Westphal et al. (2008) and Potts et al. (2006) were read. Bees were counted over a certain time period and over a certain distance. In Potts et al (2006), bees are counted for 20 minutes walking over a linear transect of 200 meters, which is repeated three times throughout the day. In Westphal et al. (2008) they conduct a similar research, except this is more extensively done. Considering the methods of these studies and our limited time, we created our own method. It was decided that the butterflies and bees would be counted and identified simultaneously while the observer was advancing along the transect, counting flowers, as it would be more time efficient than covering the same transect multiple times; once, to count the flowers, and a second time to count and identify the different pollinators.

Out of practicality and utility, we used the method that HDSR uses themselves - which is the methodology of Floron's campaign "My Berm Bloeit" - because, by following their advised methodology, we will be able to share our data with their organisation which they can then use.

Data Analysis

The data that was gathered was digitized and organized in an Excel spreadsheet **(Appendix 5)**. This was arranged by; (1) site (managed or unmanaged), (2) specific quadrant, (3) coordinates of each quadrant, (4) types of flower species, (5) number of each species found, (6) number of bees, (7) types of butterfly species, and (8) the number of each butterfly species found. Then, to analyse the data, a different table was made where the species richness, evenness, Shannon's Diversity Index, and total number of flowers was calculated of each transect. We are going to be using the Shannon Index since it takes into consideration the number of each species and the proportion of each species contributing to the total. It sums the product of each species proportion multiplied by the natural logarithm of the same proportion (Nolan & Callahan, 2006) it is one of the most commonly used indexes to measure biodiversity.

The Shannon Index was done following the guide provided by the website 'Statology' which explains how to calculate these indices step by step (Z, 2021). First, the proportions 'P_i' of each species in the transect was calculated. The proportions show the fraction that a species takes up in the transect.

$$P_i = \frac{\sum(\text{No. of Individuals of one species})}{\sum(\text{All individuals found})}$$

Formula 1: Proportional equivalence of species 'i'

Using the proportions, the natural log of P_i was found. Then, these values were inserted into the Shannon's Diversity Index formula to get the value for H.

$$H = -\sum P_i \times ln(P_i)$$

Where:

H - Shannon's Diversity Index

P_i - Proportion of individuals of species i

Formula 2: Shannon's Diversity Index

With the Shannon Index, the Shannon's Equitability Index can also be calculated. This will show the evenness of the species in the transect which indicates to what extent a species is homogeneously spread-out across the transect. This value will always range between 0 to 1; the closer the value is to 1, the more evenly it is spread out and the less diversity the transect contains.

$$E_H = \frac{H}{ln(S)}$$

Where:

E_H - Shannon's Equitability Index

H - Shannon's Diversity Index

$ln(S)$ - Natural log of Species Richness

Formula 3: Shannon's Equitability Index

A Mann-Whitney U test was conducted on SPSS to test for significance and errors. This specific test was chosen since the variables that are analysed (Species Richness, Species Evenness, Shannon’s Diversity Index, and Number of individuals found) are scale variables, there is no normal distribution, and there is no correlation between any of the variables.

For the error bars portrayed in the graphs, the standard deviation was used. This specific method was used since it “measures the dispersion of a data set relative to its mean” (Hargrave, 2021). Using the standard deviation as error bars provides a clear image of the differences to be found between the managed and unmanaged sites.

Results

The data collected provides an overview of the plant species and amount of those species found, the butterfly species and amount of those species found, as well as the amount of bees found at the researched areas along the Lekdijk. As an introduction to the results, some descriptive statistics will be outlined before visualizing the data, by portraying graphs and analysing and testing the data with statistical tests.

The highest total richness for plants in one transect was found in transect 3, a managed site, with 14 different plant species. The lowest total richness was found in transect 10, which is unmanaged, with only 3 different plant species. Looking at the most common species, the top three consists of the following species: *Boterbloem*, *Unknown 2* (see **Appendix 4**) and *Hondsdraf*. The top four rarest species were *Koninginnenkruid*, *Klaproos*, *Rolklaver* and *Unknown 10* (see **Appendix 4**). A total number of 28 flower species within all 12 transects were identified. For the managed transects, 22 different plant species were found. For the unmanaged transects, 23 different plant species were found, one species more than the managed sites. The amount of individuals found for all the species for the managed sites and unmanaged sites was also calculated, with a total amount of 2,003 individuals in the managed sites and 407 in the unmanaged sites, almost 5 times more individuals in the managed sites than in the unmanaged sites.

Only a few number of butterflies and bees were found during the experiment, too few to do noteworthy calculations, therefore only descriptive analysis will be used to discuss these findings. For the bee population, we didn’t specifically identify bee species because bees weren’t mentioned in the Floron’s index, however, it was still important to this report to include bees in the research process as the experiment looks at the relationship between main pollinator species and flower species, which, in this case, would include bees. For the managed sites, we found a total of 41 bees, while for the unmanaged site only 2 had been spotted. We did try to identify the butterfly species, however, this was hard as they fly around randomly and quickly. We found 23 butterflies in the managed sites and 6 in the unmanaged. The species found were *Klein Geaderd Witje*, *Koevinkje*, *Icarusblauwtje*, *Kleine*

Vuurvlinder, *Hooibeestje*, *Argusvlinder* and *Witje* in the managed sites and only *Argusvlinder* in the unmanaged sites.

Moving to the more analytical part of the results section, in the table below the gathered data is summed up and interpreted using the Shannon index. The table shows amongst other things, (a) the total richness per transect, (b) the evenness, (c) the Shannon index, and (d) the total number of flowers found, as well as the average and standard deviation of each of these columns.

Transect	Management	Total Richness	Evenness	Shannon Index	Total # of flower individuals
1	**Yes**	10	0.80	1.83	269
2	**Yes**	10	0.78	1.79	135
3	**Yes**	12	0.83	2.07	291
7	**Yes**	9	0.71	1.56	197
9	**Yes**	13	0.73	1.87	317
11	**Yes**	9	0.70	1.53	794
Average		10.50	0.76	1.78	333.83
±Standard Deviation		1.64	0.05	0.20	235.09
4	**No**	10	0.89	2.05	60
5	**No**	9	0.88	1.94	32
6	**No**	12	0.72	1.80	123
8	**No**	7	0.88	1.71	78
10	**No**	4	0.44	0.61	30
12	**No**	8	0.85	1.77	84
Average		8.33	0.78	1.65	67.83
± Standard Deviation		2.73	0.18	0.52	35.17

Table 1: Final table, portraying the total richness and the mean values of the richness, evenness, Shannon Index and Total number of flowers found.

Looking at the graphs for the ‘Total Richness’ and ‘Average Total Richness' (**Figure 7 & Figure 8**), slight differences can be seen between the transects, with the unmanaged sites having a smaller total richness. For two of the compared transects, the total richness was the same. In the graph Average Total Richness the error bars are overlapping which means that there is no significant difference.

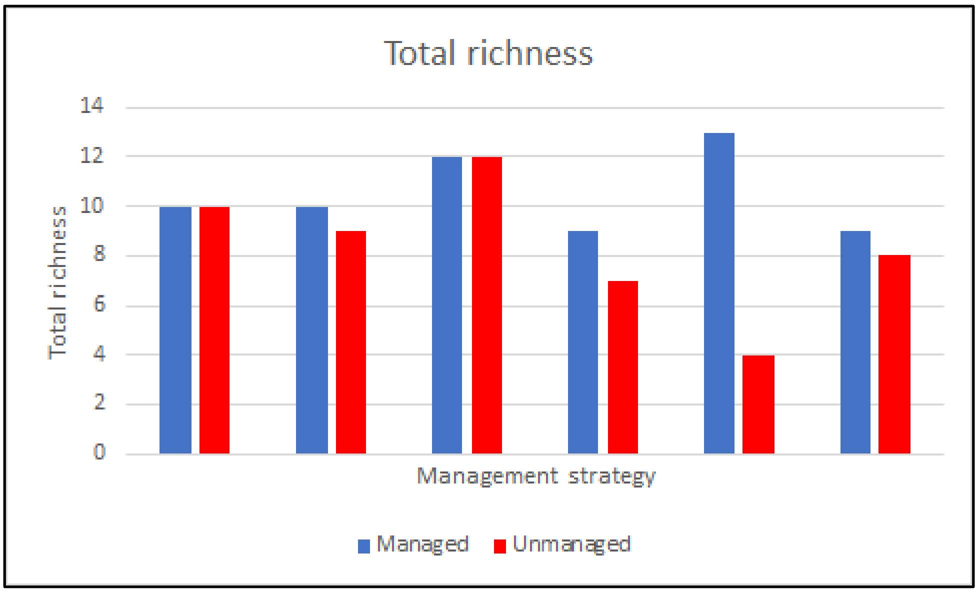


Figure 7: Graph showing the values of the total richness per transect.

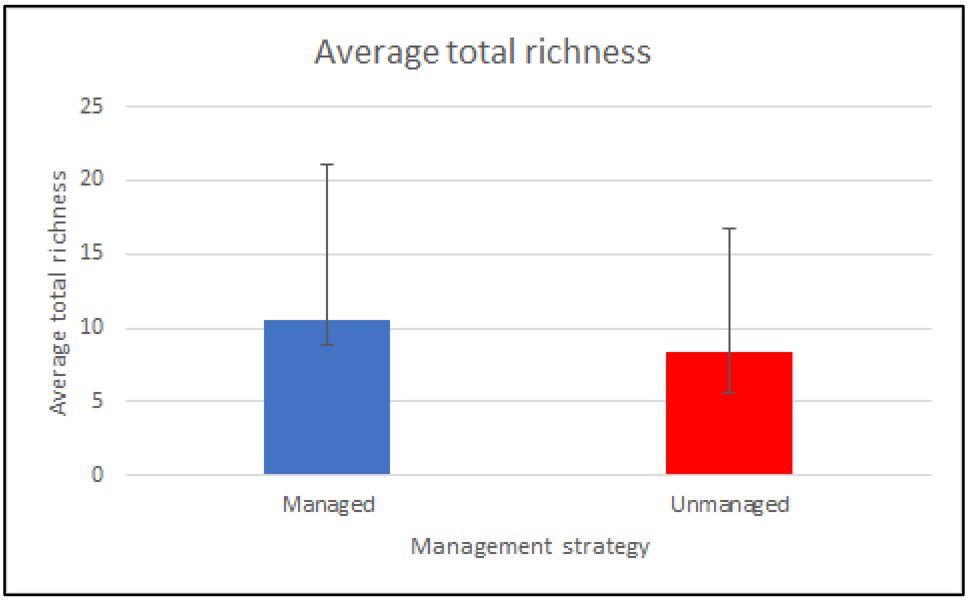


Figure 8: Graph showing the values of the average total richness of the managed and unmanaged sites, with standard deviations as error bars.

The first graph for the Evenness Index (**Figure 9**) shows the Index for each transect, with a distinction between managed and unmanaged, the second graph (**Figure 10**) shows the average taken from these values with the error bars belonging to the values. The evenness is higher in the unmanaged sites than in the managed sites 4 times, while it is higher in the managed sites only 2 times.

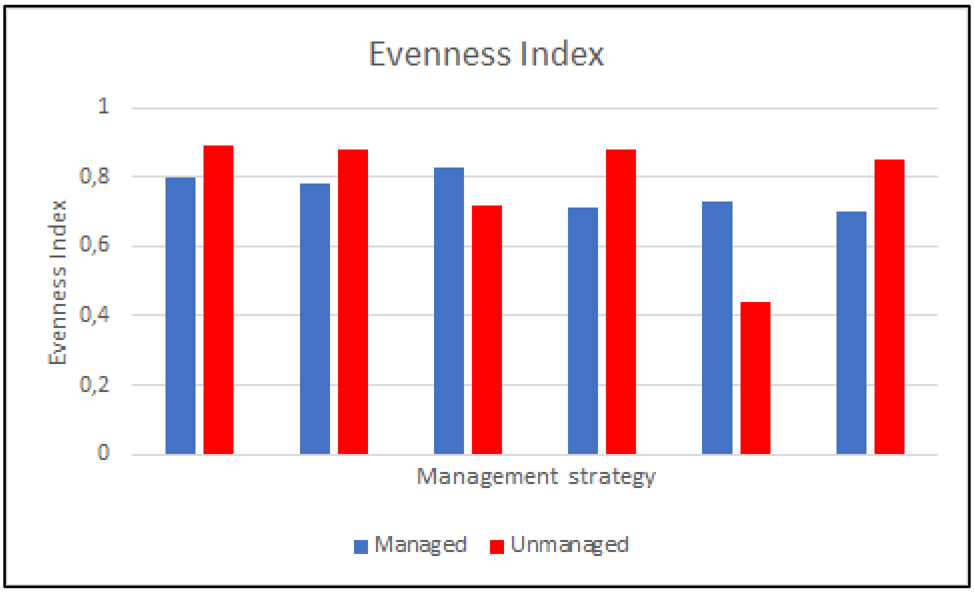


Figure 9: Graph showing the values of the Evenness Index per transect.

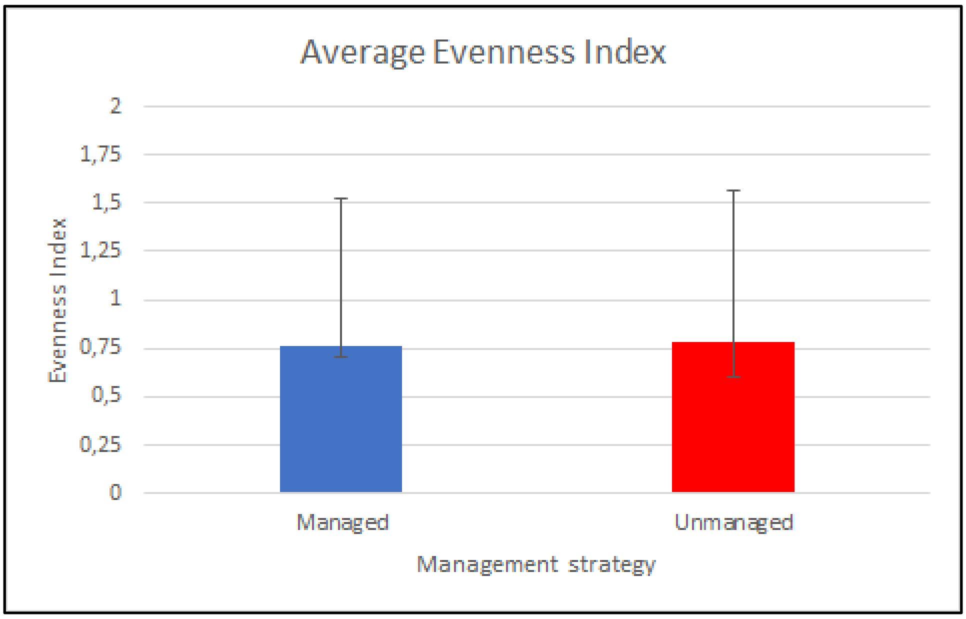


Figure 10: Graph showing the values of the average Evenness Index of the managed and unmanaged sites, with standard deviations as error bars.

A comparison is made between the Shannon index of each managed and unmanaged transect as shown in the graph below (**Figure 11**). The higher the Shannon index, the more biodiverse a transect is. The managed and unmanaged transects switch between the managed transect having a higher index and the unmanaged having a higher index.

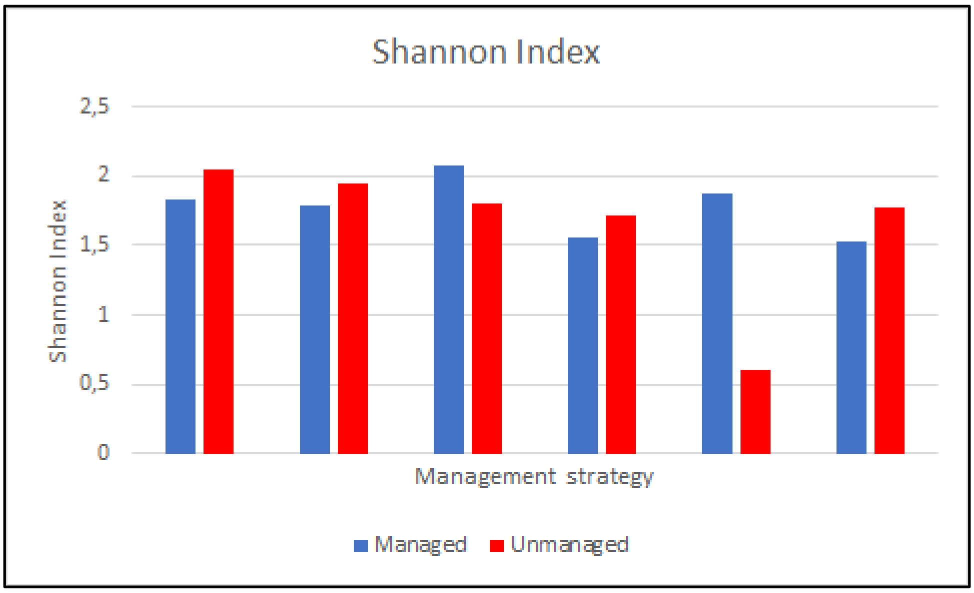


Figure 11: Graph showing the values of the Shannon Index per transect.

An average of the Shannon index is also made in **Figure 12**. This shows that, overall, the managed transect still has a slightly larger Shannon index compared to the unmanaged transects, however, the error bars overlap greatly, which means that there is no significant difference between the managed and unmanaged sites in terms of biodiversity.

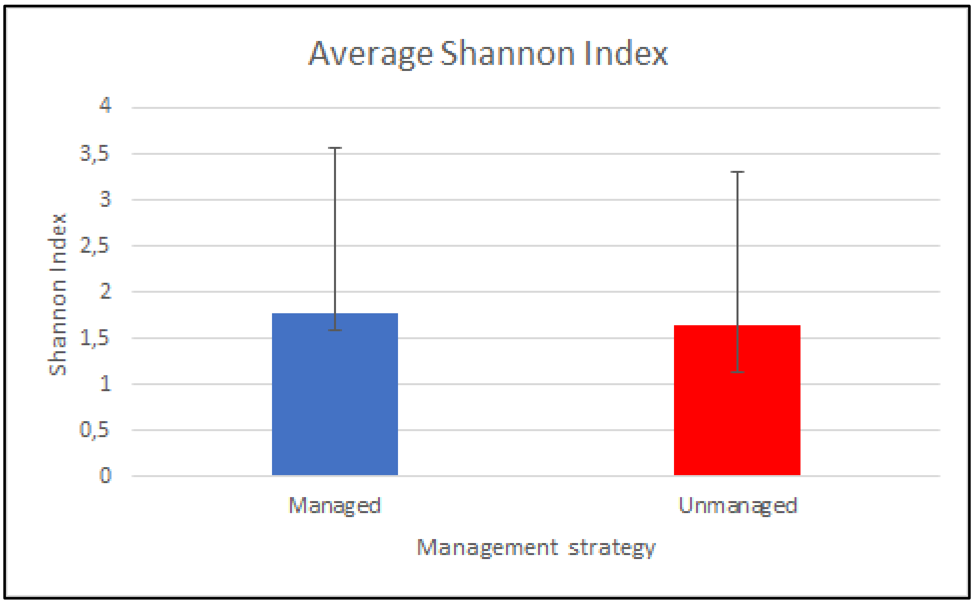


Figure 12: Graph showing the values of the average Shannon Index of the managed and unmanaged sites, with standard deviations as error bars.

The number of flower individuals found, on the other hand, had a very clear significant difference and there was a strong correlation between managed and unmanaged transects. In **Figure 13** the managed transects are all significantly larger than the unmanaged transects in terms of general flower growth, with only one unmanaged transect surpassing 100. This is further shown clearly in the 'Average amount of flower individuals found' (**Figure 14**) which displays an averaged difference between the managed and unmanaged transects.

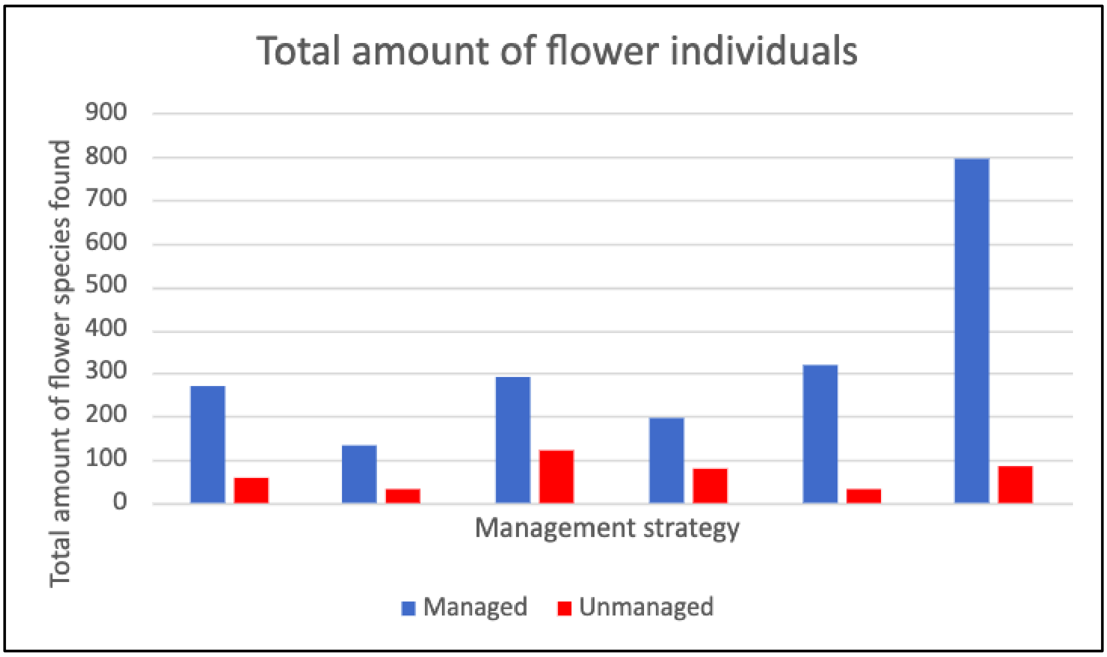


Figure 13: Graph showing the values of the total amount of flower individuals found per transect.

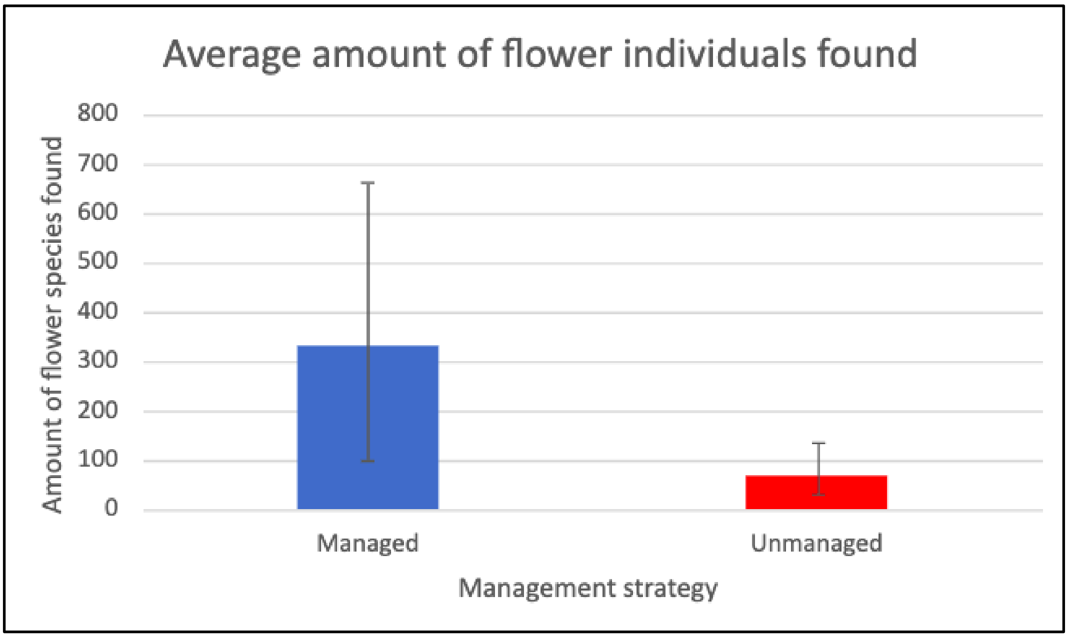


Figure 14: Graph showing the values of the average number of flower individuals found in the managed and unmanaged sites, with standard deviations as error bars.

Lastly, a Mann-Whitney U test was conducted for each of the variables with which the research question could be answered; richness, evenness and Shannon's Index (**Figure 15, 16, 17**) to measure the significance of the collected data. This statistical test showed that the p-value (Asymp. sig. (2-tailed)) was above 0.05 which means that there was no significant difference in biodiversity between managed and unmanaged sites.

Test Statistics[a]

	T_Richness
Mann-Whitney U	8,500
Wilcoxon W	29,500
Z	-1,546
Asymp. Sig. (2-tailed)	,122
Exact Sig. [2*(1-tailed Sig.)]	,132[b]

a. Grouping Variable: Management

b. Not corrected for ties.

Figure 15: The Mann-Whitney U statistical test of the Total Richness values

Test Statistics[a]

	Evenness
Mann-Whitney U	10,000
Wilcoxon W	31,000
Z	-1,283
Asymp. Sig. (2-tailed)	,199
Exact Sig. [2*(1-tailed Sig.)]	,240[b]

a. Grouping Variable: Management

b. Not corrected for ties.

Figure 16: The Mann-Whitney U statistical test of the Evenness values

Test Statistics[a]

	Shannon_Index
Mann-Whitney U	17,000
Wilcoxon W	38,000
Z	-,160
Asymp. Sig. (2-tailed)	,873
Exact Sig. [2*(1-tailed Sig.)]	,937[b]

a. Grouping Variable: Management

b. Not corrected for ties.

Figure 17: The Mann-Whitney U statistical test of the Shannon Index values

Because a notable difference was observed on the amount of total individuals between managed and unmanaged sites an additional Mann-Whitney U test was performed on this parameter.

Test Statistics[a]

	T_Individuals
Mann-Whitney U	,000
Wilcoxon W	21,000
Z	-2,882
Asymp. Sig. (2-tailed)	,004
Exact Sig. [2*(1-tailed Sig.)]	,002[b]

a. Grouping Variable: Management

b. Not corrected for ties.

Figure 18: The Mann-Whitney U statistical test of the Total amount of Individuals

The test result indicated the existence of a significant statistical relationship between management status and total number of individuals since the Asymp. Sig (2-tailed) value is 0,004 which is considerably lower than 0,05. This confirms that applying the management techniques does indeed make a difference on plant population, on its density. The sub-question: *How does plant species richness, evenness, abundance and the Shannon Index differ between managed and unmanaged sites?* can then be answered in terms of abundance, plant species abundance differs between managed and unmanaged sites with a significantly higher value on the managed sites.

Discussion

In this section, the results and what they mean to the research question will be discussed. Furthermore, it will be discussed what could have potentially influenced the results, and what could be improved, and the research questions are mentioned. An elaborate answer to the questions will be given in the conclusion.

First, we found that the results of our natural experiment are mixed. The graphs represent the different aspects of biodiversity measured, however, the tests used to analyze the species richness, evenness and Shannon's diversity Index. Those do not show a difference that was significant enough. This indicates that there is no correlation between the level of biodiversity of a transect and its management status.

When looking at the species richness, something noticeable between managed and unmanaged sites can be seen. According to our hypothesis, the highest total richness would be found in a managed transect. However, this was contradicted by our results, which found a larger total of species on the unmanaged transects, albeit by only one species. On the other hand, this was negated when averaging the results, which showed that the managed transects had a larger average species richness per transect than unmanaged transects.

Nevertheless, the species evenness was generally higher on the unmanaged sites, meaning that even though there were less individuals, they were more evenly distributed between different species. However, this finding was found to be insignificant as indicated by the error bars on both evenness values might overlap each other, as shown in ***Figure 10***. Furthermore, the Mann-Whitney U test (***Figure 16***) showed that there was no significance in the difference between managed and unmanaged, which indicates that there is no correlation between the level of species evenness and the present management strategy.

Furthermore, the Shannon Index analysis on both managed and unmanaged sites vary throughout transect sites. Some managed transects have a higher Shannon index value than the unmanaged ones, and in some the opposite occurs. The average shows that the managed sites have a slightly higher Shannon Index value, but once again, the error bars, as seen in ***Figure 12*** are relatively large and could easily change the interpretation of the graph. In addition, the Mann-Whitney U test (***Figure 17***) on the data gathered for this index shows no significant difference.

To sum up, the Mann-Whitney U tests showed no significant statistical relationship for the managed and unmanaged sites of the richness, evenness and the Shannon Index. This means that we could not find a clear relationship between management strategies and biodiversity increase through richness, evenness and Shannon Index. An explanation for the lack of correlation could be that the management strategies do not enhance the amount of species. As mentioned in the *Literature Review*, mowing reduces competition (Humbert, 2012) which inherently decreases the number of species present and thus also lowers the level of biodiversity. Another explanation could be that we only had a sample size of 6, and a larger sample size could showcase a more significant difference.

While there was no significant difference found when looking at evenness, richness and the Shannon's Diversity Index, there was a significant difference found in the abundance of individual flowers (***Figure 18***): the managed sites had more individuals per species than unmanaged sites; 2003 individuals at managed sites vs. 407 individuals at unmanaged sites. This significance in difference was confirmed by the Mann-Whitney U test (***Figure 18***) which computed a significance of 0.004. This shows how management strategies clearly affect population density which is in line with our expectations.

The results of the richness, evenness, Shannon's Index and the Mann-Whitney U test above make it possible to formulate an answer to the sub question: '*How does plant species richness, evenness and the Shannon Index differ between managed and unmanaged sites?*'

After looking at the results of the butterflies and bees, we concluded that there was no possibility to perform a statistical test, since not enough data was collected. Furthermore, a limitation that we want to point out is that there was some concern about counting the same pollinator multiple times. If we had collected less limited data on these pollinators, this would have increased the margin of error, decreasing the significance of our results. However, because of the lack of information that we obtained, this won't affect our result or conclusion in any substantial way, it will only hinder our ability to answer the second sub-question: '*How do butterflies and bees differ in the populations and abundance between sites?*'

Another limitation that should be highlighted is the uncontrollable conditions of the weather which also had an effect on measuring pollinator species. For example, the measurements were done on different days, meaning there were most likely (slightly) different weather conditions at the measurement sites, which could influence the data collected. As mentioned before, the windy weather conditions might have decreased our results on the number of pollinators found because these shifting conditions cause less insect pollinators to be present.

There was also a slight difference in the number of quadrants that were measured. One group member only measured ten quadrants, while eleven quadrants had to be done for our research. This could have had an impact on the values of the indexes that are included in our report, since less flowers have been found, however, by averaging the number of individuals found over 10 quadrants, the end result will still end up being around the same as measuring 11 quadrants and dividing it by 11.

In addition to this, when walking along the transect it was apparent that in between the quadrants a significant amount of additional plant species were seen. In some cases, there were plants in between the quadrants which missed out of being included in the quadrant, so it was not noted down and, therefore, it seems as if these species were not present, which could create a distorted picture of a transect. However, since a standardized method was used, it most likely does not influence the actual patterns in plant species found.

There are also a few unavoidable biases in the data collection. Firstly, because we counted the flowers, bees and butterflies with 10 different people in total, every pair most likely had a somewhat of a different approach. This might have caused slightly different results than when one pair would have done all of the data collection. It also means that human mistakes can be made. Unfortunately, this is a bias that cannot be avoided when conducting research. Lastly, it should be mentioned that the unmanaged sites were not randomly chosen. Since we had to follow the coordinates of managed sites, and to save on time, we picked unmanaged parts of the dike close to the coordinates of the managed sites. Additionally, when counting bees and butterflies, the path which the observer follows should be random, as mentioned in Potts et al. (2006) and Westphal et al. (2008), however, since the observations took place on a dike, we had to follow the direction of the road as it was harder to reach locations on the side of the dike.

Conclusion

Based on a descriptive analysis of the data on pollinators, there is a slight indication that at managed sites more butterflies and bees were present. However, too little data was collected for the pollinators to conduct a statistical test. This was due to altering weather conditions, such as strong wind, and limited time boundaries, which hindered our ability to collect a sufficient sample size. Thus, no conclusion can be drawn on the sub-question: '*How do butterflies and bees differ in the populations and abundance between sites?*', other than the bee and butterfly population were much larger in the managed sites than in the unmanaged sites. However, since it is not possible to do analytical data analysis, we are not able to draw this conclusion definitively.

Yet, this was not the case when measuring flowers, as this variable was not affected by daily changes in weather. The Mann-Whitney U test showed no significant difference between the plant biodiversity in the managed and the unmanaged sites with a difference of 0.13, the total species richness only differed by one species, and species evenness differed by an average of 0.02. It is visibly clear without having done a Mann-Whitney U test that the differences between managed sites and unmanaged sites do not differ nearly enough as was expected. However, the only difference that was seen was that there was a 4:1 ratio in flower individuals found between managed and unmanaged sites. Thus as an answer to the question: '*How does plant species richness, evenness, abundance of individuals, and the Shannon Index differ between managed and unmanaged sites?*', it can be said that there is no significant difference between managed and unmanaged sites in terms of richness, evenness, and Shannon index. Only the abundance of individuals had any substantial difference.

In answer to the main research question: '*How does the management of plant species affect biodiversity along the Lekdijk?*', the management of plant species does not affect biodiversity along the Lekdijk. Since the outcome of the Mann-Whitney U test showed that the results about plant species were not significant, and we cannot perform scientific analysis and statistical tests for the bees and butterflies, we have to reject our hypothesis: *The management of flowers along the Lekdijk will increase the biodiversity of both the plant and the pollinator species*'.

Our suggestions for future research would be to not use biodiversity as a main indicator for the success of certain management strategies, such as mowing, as our research has shown no relation between the two. Moreover, we suggest more time should be spent when measuring bee and butterfly populations as their appearance is dependent on daily conditions. We also suggest that management strategies should continue the way they are as their ability to increase flower populations yields positive results. Lastly, it would be useful to continue this research at other dike locations in the Netherlands that are managed to see if our result is recurring or if there is a noticeable difference.

Relevance and integration possibilities

To discuss the relevance and integration possibilities of biodiversity along the Lekdijk, it is of importance to note that the topic discussed in this report is seen as a subtopic of a larger topic, namely 'sustainable water management'. In connection to this topic, a few subtopics are identified. The gathered data from these subtopics are utilized to answer the overarching (research) question: "How can we organize our use of several water bodies sustainably along the surroundings of the Utrecht Heuvelrug?".

To paint the general picture of the sustainability of water management, it is critical that all of the subtopics are researched and connected. In this report the other subtopics will not be described in great detail, yet the connections that are found between these topics will be outlined. The subtopics focus on a range of aspects of water management and how to deal with water sustainably in the area of the Utrechtse Heuvelrug. This research uses a natural science method to measure if the management strategies applied along the dike are effective, while an additional subtopic looks at the perception of these management strategies, providing a complete picture which takes into account the natural and social aspect of what there is to know about the Lekdijk. The other topics look at other aspects of this issue, namely the potential water storage areas, the groundwater levels at the Utrechtse Heuvelrug, droughts and farmers and the water quality in urban areas.

To identify other connections between the topics it can be explained that the first three topics, namely water storage, groundwater levels and droughts together focus on what to do during possible droughts (most likely due to climate change), while the topic of this report and the social perception of this experiment focus more on what happens when too much water enters the Netherlands (also most likely due to climate change). Yet, in the end, everything can be connected through mentioning that everything done for 'sustainable water management' aims to mitigate and adapt to the water issues caused due to climate change. An increase in biodiversity and flower population size will also lead to an increase in the pollinator population in the area, which can help with food production as pollinators are a vital part of the food production process (Food and Agriculture Organization of the United Nations, 2018). These are just some examples of the many connections to be found in these topics.

Since these other topics will focus on different aspects of water management, this also results in different research methods being executed to gather data on these topics. Because other research methods will also be used, other types of data will be collected, which gives not only more data, but it also gives a wider variety of data. Not only the natural aspect is taken into account, since that is what is measured in the topic of this report, but also social science plays a significant role. This creates an interdisciplinary and complete picture of what there is to know about sustainable water management.

Reference list

Berendse, F., van Ruijven, J., Jongejans, E., & Keesstra, S. (2015). Loss of Plant Species Diversity Reduces Soil Erosion Resistance. *Ecosystems*, *18*(5), 881–888. https://doi.org/10.1007/s10021-015-9869-6

Biesmeijer, J. C., Roberts, S. P. M., & Reemer, M. (2006, July). *Parallel Declines in Pollinators and Insect-Pollinated Plants in Britain and the Netherlands* (Vol. 313, Issue 5785, pp. 351–354). American Association for the Advancement of Science. https://doi.org/10.1126/science.1127863

Blüthgen, N., & Klein, A. M. (2011). Functional complementarity and specialisation: The role of biodiversity in plant–pollinator interactions. *Basic and Applied Ecology*, *12*(4), 282–291. https://doi.org/10.1016/j.baae.2010.11.001

Cizek, O., Zamecnik, J., Tropek, R., Kocarek, P., & Konvicka, M. (2011). Diversification of mowing regime increases arthropods diversity in species-poor cultural hay meadows. *Journal of Insect Conservation*, *16*(2), 215–226. https://doi.org/10.1007/s10841-011-9407-6

Elle, E., Elwell, S. L., & Gielens, G. A. (2012). The use of pollination networks in conservation. This article is part of a Special Issue entitled "Pollination biology research in Canada: Perspectives on a mutualism at different scales". *Botany*, *90*(7), 525–534. https://doi.org/10.1139/b11-111

Feest, A., van Swaay, C., & van Hinsberg, A. (2014). Nitrogen deposition and the reduction of butterfly biodiversity quality in the Netherlands. *Ecological Indicators*, *39*, 115–119. https://doi.org/10.1016/j.ecolind.2013.12.008

Food and Agriculture Organization of the United Nations (2018). *Why bees matter, The importance of bees and other pollinators for food and agriculture*, Retrieved from http://www.fao.org/3/I9527EN/i9527en.pdf

Hargrave M., (2021). *Standard Deviation*. Retrieved from, https://www.investopedia.com/terms/s/standarddeviation.asp#:~:text=A%20standard%20deviation%20is%20a,deviation%20relative%20to%20the%20mean.

Haveman, R., & Stortelder, A. H. F. (2006, januari). *De effecten van biologische landbouw op biodiversiteit – een kritisch literatuuroverzicht*. https://www.researchgate.net/profile/Rense-Haveman/publication/258507603_De_effecten_van_biologische_landbouw_op_biodiversiteit_-_een_kritisch_literatuuroverzicht/links/00b4952861df70e7b8000000/De-effecten-van-biologische-landbouw-op-biodiversiteit-een-kritisch-literatuuroverzicht.pdf

HDSR, (2018), Bloemrijke Lekdijk afgelopen tijd in volle glorie, Retrieved from https://www.hdsr.nl/zoeken/@74745/bloemrijke-lekdijk/

HDSR. (2016, March). *Maaibeheer voor bloemrijke, veilige dijken*. HDSR. https://www.hdsr.nl/werk/veilige-dijken/maaibeheer/

HDSR, (n.d.), *Ons werk*, Retrieved from https://www.hdsr.nl/werk/

HDSR, (n.d.), *Sterke Lekdijk*, Retrieved from https://www.hdsr.nl/buurt/sterke-lekdijk/

Hoffman, F., & Quack, M. M. (2008). *The importance of biodiversity for pollination* (No. 1891360). Wageningen Environmental Research. https://www.landschap.nl/wp-content/uploads/2008-3_129-131.pdf

Humbert, J. Y., Pellet, J., Buri, P., & Arlettaz, R. (2012). Does delaying the first mowing date benefit biodiversity in meadowland? *Environmental Evidence*, *1*(1), 9. https://doi.org/10.1186/2047-2382-1-9

Intergovernmental Panel on Climate Change IPCC, Geneva (Switzerland). (2002, July). *Climate Change and Biodiversity* (IPCC-TP-5). IPCC.

KNMI, (n.d.). *Klimaatverandering*, Retrieved from https://www.knmi.nl/producten-en-diensten/klimaatverandering

Liebrand, C. I. J. M. (1999, April). *Restoration of species-rich grasslands on reconstructed river dikes*. Department of Environmental Sciences. https://edepot.wur.nl/198965

L. L. Eberhardt. (1978, Jan) *Transect Methods for Population Studies.* The Journal of Wildlife Management. *https://doi-org.proxy.library.uu.nl/10.2307/3800685*

Mijn berm bloeit! (2021). Floron. https://www.floron.nl/bermen

Nolan, Kathleen & Callahan, Jill. (2006). Beachcomber Biology: The Shannon-Weiner Species Diversity Index. Proc. Workshop ABLE. 27, Retrieved from https://www.researchgate.net/publication/267230639_Beachcomber_Biology_The_Shannon-Weiner_Species_Diversity_Index

Okpiliya, F. I. (Ph.D). (2012) *Ecological Diversity Indices: Any Hope for One Again?. Department of Geography & Environmental Science.* University of Calabar, Nigeria, Retrieved from https://core.ac.uk/download/pdf/234662987.pdf

Planbureau voor de Leefomgeving, (n.d.), *Correctie formulering over overstromingsrisico Nederland in IPCC-rapport*, Retrieved from https://www.pbl.nl/correctie-formulering-over-overstromingsrisico

Potts, S. G., Petanidou, T., Roberts, S., O'Toole, C., Hulbert, A., & Willmer, P. (2006). Plant-pollinator biodiversity and pollination services in a complex Mediterranean landscape. *Biological Conservation*, *129*(4), 519–529. https://doi.org/10.1016/j.biocon.2005.11.019

Rathcke, B. J., & Jules, E. S. (1993). Habitat fragmentation and plant-pollinator interactions. *Pollination Biology in Tropics*, *65*(3), 273–277.

https://www-jstor-org.proxy.library.uu.nl/stable/24095130?seq=1#metadata_info_tab_contents

Rijksoverheid, (2013), *Biodiversiteitsverlies in Nederland, Europa en de wereld, 1700-2010,* Retrieved from https://www.clo.nl/indicatoren/nl144002-ontwikkeling-biodiversiteit-msa

Smith, A. L., Barrett, R. L., & Milner, R. N. C. (2018). Annual mowing maintains plant diversity in threatened temperate grasslands. *Applied Vegetation Science*, *21*(2), 207–218. https://doi.org/10.1111/avsc.12365

Tamis, W. L. M., Van't Zelfde, M., Van Der Meijden, R., & De Haes, H. A. U. (2005). *Changes in Vascular Plant Biodiversity in the Netherlands in the 20th Century Explained by their Climatic and other Environmental Characteristics*. https://doi.org/10.1007/s10584-005-5287-7

Thomas, C.D., Cameron, A., Green, R.E. et al. (16 more authors) (2004) *Extinction risk from climate change. Nature*, 427 (6970). pp. 145-148. ISSN 0028-0836, Retrieved from, https://eprints.whiterose.ac.uk/83/1/thomascd1.pdf8

Van Koningsveld, M., Mulder, J. P. M., Stive, M. J. F., Van Der Valk, L., & Van Der Weck, A. W. (2008). Living with Sea-Level Rise and Climate Change: A Case Study of the Netherlands. *Journal of Coastal Research*, *242*, 367–379. https://doi.org/10.2112/07a-0010.1

Van Loon-Steensma, J. M., & Huiskes, R. H. P. J. (2017, April). *Meer biodiversiteit met brede groene dijken?* (No. 2802). Wageningen Environmental Research. https://library-wur-nl.proxy.library.uu.nl/WebQuery/wurpubs/fulltext/412209

Westphal, Catrin & Bommarco, Riccardo & Carré, Gabriel & Lamborn, Ellen & Morison, Nicolas & Petanidou, Theodora & Potts, Simon & Roberts, Stuart & Rgyi, Hajnalka & Tscheulin, Thomas & Vaissi, Bernard & Woyciechowski, Michal & Biesmeijer, Jacobus & Kunin, William & Settele, Josef & Ingolf, And. (2008). *Measuring bee diversity in different European habitats and biogeographical regions. Ecological Monographs.* 78. 653-671. 10.1890/07-1292.1.

Z. (2021, March 29). *Shannon Diversity Index: Definition & Example*. Statology. https://www.statology.org/shannon-diversity-index/

Appendices

Appendix 1

Flower Species Data

Verge # Transect #	Species Present (yes/no)	Number of individuals
Andere gele composieten		
Braam		
Boerenwormkruid		
Boterbloem		
Distel		
Duizendblad		
Gewone berenklauw		
Gewone margriet		
Gewone paardenbloem		
Gewone smeerwortel		
Guldenroede		

Hondsdraf		
Jakobskruiskruid		
Knoopkruid		
Koninginnekruid		
Pinksterbloem		
Rode klaver		
Rolklaver		
Struikhei		
Vogelwikke		
Wilgenroosje		
Witte dovenetel		
Witte klaver		
Zandblauwtje		

Table 1: Table with the plant species that can potentially be found, with columns to note down if the species are present, and in what amounts they are present.

Appendix 2

<u>Butterfly Species Data</u>

Verge # Transect #	Species Present (yes/no)	Number of individuals
Argusvlinder		
Bruin blauwtje		
Bruin zandoogje		

Groot dikkopje		
Hooibeestje		
Icarusblauwtje		
Kleine vuurvlinder		
Klein geaderd witje		
Koevinkje		
Oranjetipje		
Oranje zandoogje		
Zwartsprietdikkopje		

Table 2: Table with the butterfly species that can potentially be found, with columns to note down if the species are present, and in what amounts they are present.

Appendix 3

<u>Bee Presence Data</u>

Verge # Transect #	Bees Present (yes/no)	Number of individuals

Table 3: Table with columns to indicate if there were bees present at the sites and if so, in what amounts.

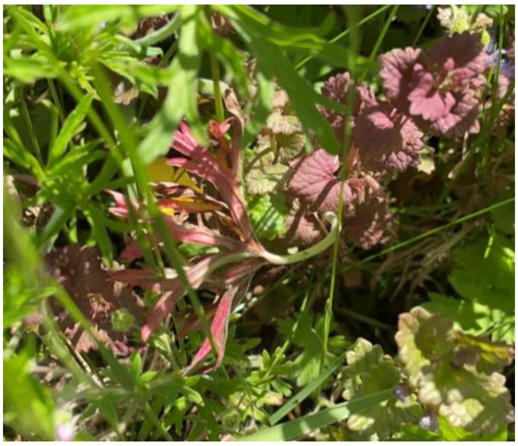
Appendix 4

Table of Unknown plant Species

Name	Image
Unknown 1	
Unknown 2	

Unknown 3	
Unknown 4	
Unknown 5	

Unknown 6	
Unknown 7	
Unknown 8	

Unknown 9	
Unknown 10	
Unknown 11	

Appendix 5

Site	Quadrant/Transect	Species	Amount	Bees	Butterflies	Amount	Species Richness (S)	Log of Species Richness (ln(S))	Species Evenness (E)	S
Managed site Indi 2	1.00	Andere gele composieten	8.00	12.00	Klein geaderd v	2.00				
		Distel	20.00		Unknown	1.00				
		Paardenbloem	3.00							
		Rode klaver	13.00							
		Unknown 1	4.00				5.00	1.61	0.87	
	2.00	Andere gele composieten	12.00							
		Hondsdraf	8.00							
		Unknown 1	9.00				3.00	1.10	0.99	
	3.00	Andere gele composieten	5.00							
		Hondsdraf	13.00							
		Madeliefje	1.00							
		Unknown 1	8.00							
		Unknown 2	4.00				5.00	1.61	0.86	
	4.00	Andere gele composieten	4.00							
		Distel	13.00							
		Hondsdraf	12.00							
		Unknown 1	1.00				4.00	1.39	0.80	
	5.00	Andere gele composieten	9.00							
		Madeliefje	2.00							
		Paardenbloem	3.00							
		Rode klaver	4.00							